HMS Calorimeter in HCANA

Recent progress

Vardan Tadevosyan
Simon Zhamkochyan

Hall A/C software meeting

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Calibration replay

- h_cal_replay.cpp (<RunNumber, NumberOfEvents>)

  replays a run, generates ntuple with raw data

  Similar to hodtest.C *and* hodtest_mkj.C*, with minor modifications like cut and output files, MaxEventToReplay etc.*

  - Works on single track electron events
  - Selects electrons in Gas Cherenkov
  - Also makes use of β_{TOF} for e^- selection

Calibration replay

Event selection done in hcal_replay_cuts.def:

Block: Reconstruct

one_track	H.tr.n==1
one_clust	H.cal.nclust==1
one_sh_track	H.cal.ntracks==1
in_delta	H.tr.tg_dp>-10.&&H.tr.tg_dp<10.
good_cer	H.cer.npesum>3.
good_beta	H.tr.beta>0.740&&H.tr.beta<0.935

This version is for calibration from scratch (no calibration constants exist,
first time calibration).
Reconstruct_master one_track && one_clust && in_delta && good_cer && good_beta

This version can be used for iterative calibration (improve existing constants).
#Reconstruct_master one_track && one_sh_track && in_delta && good_cer &&
#good_beta

Calibration replay

Ntuple selection done in output_hcal_replay.def:

```
#
# Output definition for the HMS calorimeter calibration.
#

block H.cal.*                    ← comprises pedestal subtracted ADC signals
variable H.cer.npesum
variable H.tr.beta
variable H.tr.p
variable H.tr.tg_dp
variable H.tr.y      #Y FP
variable H.tr.x      #X FP
variable H.tr.ph     #tan(phi), wrt Y axis
variable H.tr.th     #tan(theta), wrt X axis
variable H.tr.n                  #number of tracks
```

Calibration Algorithm

Definitions:

$q = \begin{pmatrix} q_1 \\ \vdots \\ q_N \end{pmatrix}$ -- QDC signals, $\alpha = \begin{pmatrix} \alpha_1 \\ \vdots \\ \alpha_N \end{pmatrix}$ – calibration constants,

$e_0 = E(e)$ – projectile mean energy, $q_0 = E(q)$ – mean signals,

$e_R = \alpha^T q$ – reconstructed energy.

Constrained minimization: Minimize variance of the reconstructed energy with respect to the projectile energy

$$\text{Minimize } E(e_R - e)^2 \text{ subject to } \alpha^T q_0 = e_0$$

Solution:

$$\alpha_C = \frac{e_0 - \alpha_U^T q_0}{q_0^T Q^{-1} q_0} Q^{-1} q_0 + \alpha_U$$

$$Q = E(qq^T),\ \alpha_U = Q^{-1} q_e,\ q_e = E(eq)$$

Ts.Amatuni, On the calibration of segmented full absorption calorimeters. Unpublished.

Calibration script

...

In hcal_calib.cpp:

#include "THcShowerCalib.h" ← the Shower calibration class

...

theShowerCalib.Init(); *// Initialize constants and variables, histogram declaration*

theShowerCalib.CalcThresholds();

Calculate Thresholds on the uncalibrated Edep/P. These are used mainly to exclude potential hadronic events due to the Gas Cherenkov inefficiency.

- Build energy distribution using uncalibrated gains: 0.5 for the first 2 columns, 1 for others
- Set thresholds as ±3*RMS

theShowerCalib.ComposeVMs(); // Fill in vectors and matrices

theShowerCalib.SolveAlphas(); // Solve for the calibration constant

theShowerCalib.SaveAlphas(); // Save the gain constants to use in the analysis

theShowerCalib.FillHEcal(); // Fill histograms

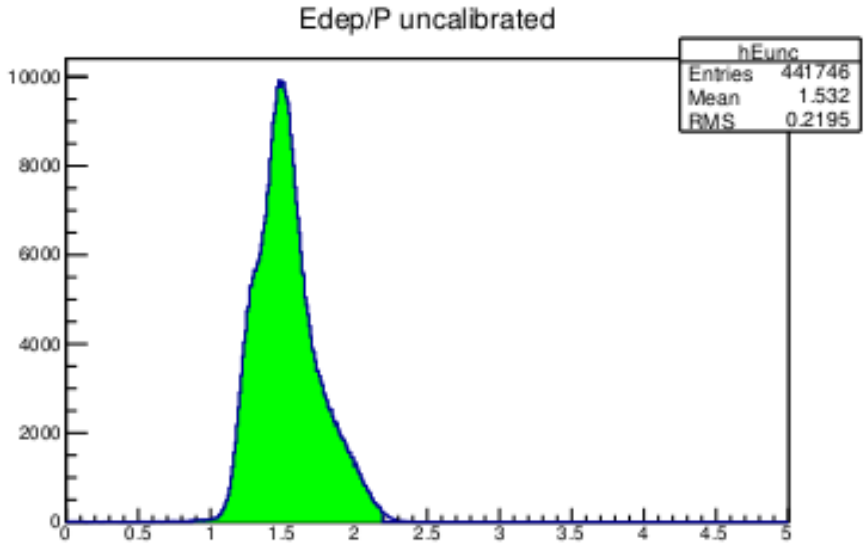
Calibration output

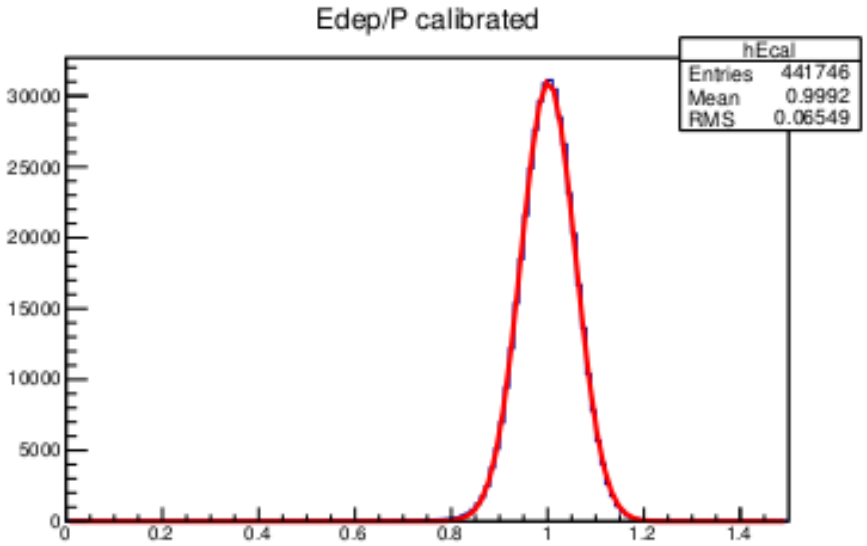
Calibration constants are saved in hcal.param.<RunNumber>, in format compatible with engine:

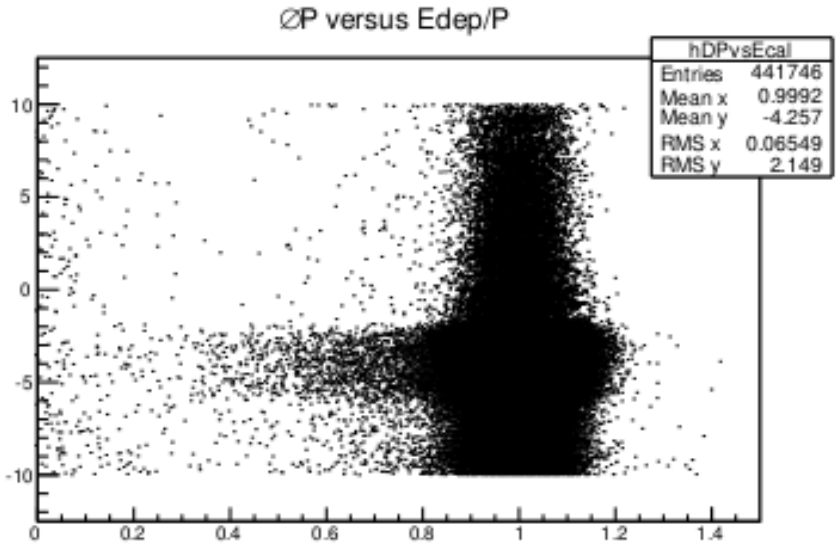
```
; Calibration constants for run 52949, 439596 events processed

hcal_pos_gain_cor= 0.430, 0.354, 0.416, 0.385, 0.247, 0.511, 0.550, 0.380, 0.501, 0.342, 0.378, 0.389, 0.000,
                   0.374, 0.424, 0.341, 0.386, 0.448, 0.484, 0.224, 0.448, 0.302, 0.272, 0.331, 0.638, 0.580,
                   0.604, 0.626, 0.602, 0.852, 0.628, 0.655, 0.465, 0.547, 0.713, 0.726, 0.522, 0.635, 0.000,
                   0.786, 0.603, 0.580, 0.731, 0.732, 0.828, 0.855, 0.742, 0.830, 0.625, 0.699, 0.738, 0.000,
hcal_neg_gain_cor= 0.419, 0.270, 0.287, 0.366, 0.353, 0.050, 0.185, 0.445, 0.236, 0.337, 0.203, 0.171, 0.000,
                   0.404, 0.357, 0.387, 0.510, 0.331, 0.337, 0.454, 0.301, 0.469, 0.361, 0.340, 0.380, 1.102,
                   0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000,
                   0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000,
```

hcal_calib.cpp was checked against engine, for the same cuts difference in calibration constants is 0.001 or less.

Graphics Output







Difference in energy between golden track in hcana and best track in Engine

For comparisons, some modifications have been made in hcana:

In THcShowerCluster::clX method:

```
// X coordinate of center of gravity of cluster,
 // calculated as hit energy weighted average.
 // Put X out of the calorimeter (-75 cm), if there is no en
 // in the cluster.
 //
 Double_t clX() {
   Double_t x_sum=0.;                                    |
   Double_t Etot=0.;                                     |
   for (THcShowerHitIt it=THcShowerHitList::begin();     |
        it!=THcShowerHitList::end(); ++it) {             |
     x_sum += (*it)->hitX() * (*it)->hitE();             |
     Etot += (*it)->hitE();                              |
                                                         |
                                                         |
                                                         |
                                                         |
                                                         |
                                                         |
                                                         |
                                                         |
   }                                                     |
```

```
// X coordinate of center of gravity of cluster,
 // calculated as hit energy weighted average.
 // Put X out of the calorimeter (-75 cm), if there is no en
 // in the cluster.
 //
 Double_t clX() {
   //    Double_t x_sum=0.;
   //    Double_t Etot=0.;
   float x_sum=0.;
   float Etot=0.;

   //    for (THcShowerHitIt it=THcShowerHitList::begin();
   //   it!=THcShowerHitList::end(); ++it) {

   // Consistent with Engine.
   //
   for (THcShowerHitIt it=THcShowerHitList::end()-1;
        it>=THcShowerHitList::begin(); it--) {
     //x_sum += (*it)->hitX() * (*it)->hitE();
     //Etot += (*it)->hitE();
     x_sum += float((*it)->hitX()) * float((*it)->hitE());
     Etot += float((*it)->hitE());
   }
```

Make calculations in float precision, in the same order as in Engine

Modifications in hcana

In THcShower::MatchCluster method:

```
// Since hits and clusters are in reverse order (with respect to Engine),
  // search backwards to be consistent with Engine.
  //
  for (Int_t i=fNclust-1; i>-1; i--) {

    THcShowerCluster* cluster = (*fClusterList).ListedCluster(i);

    Double_t dx = TMath::Abs( (*cluster).clX() - XTrFront );

    if (dx <= (0.5*BlockThick[0] + fSlop)) {
      fNtracks++;  // number of shower tracks (Consistent with engine)
      if (dx < deltaX) {
        mclust = i;
        deltaX = dx;
      }
```

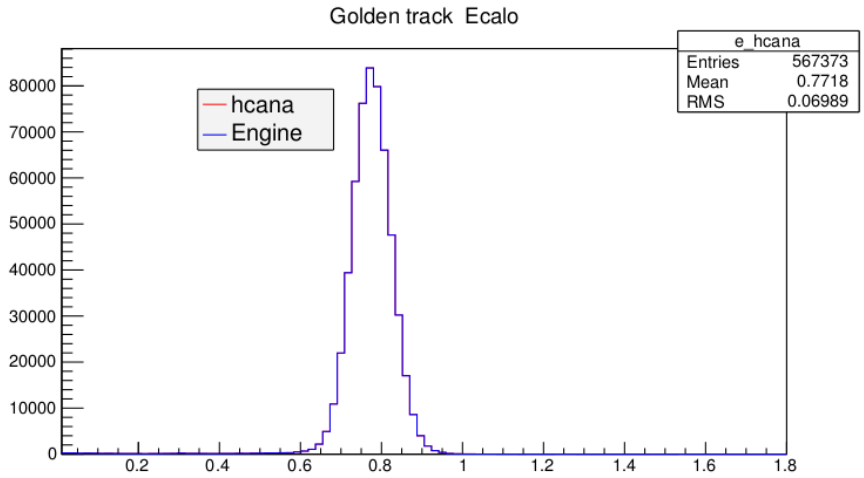
Search clusters for track association in the same order as in Engine.

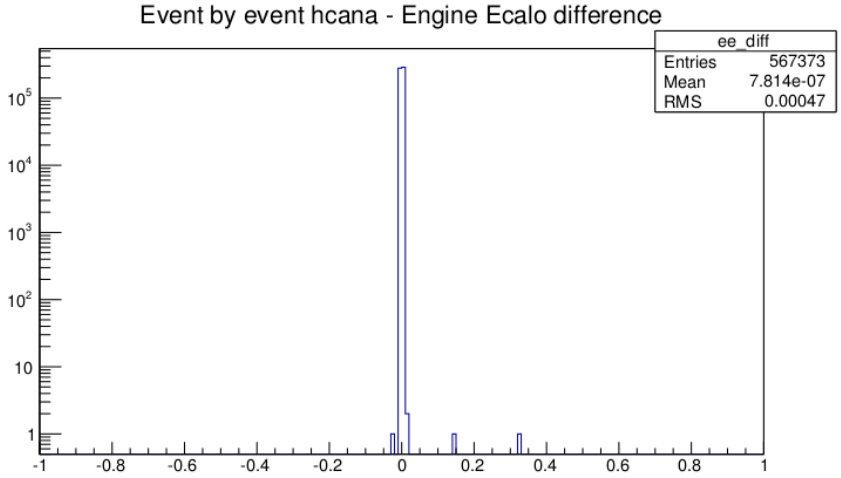
In THcShower::IsNeighbour method:

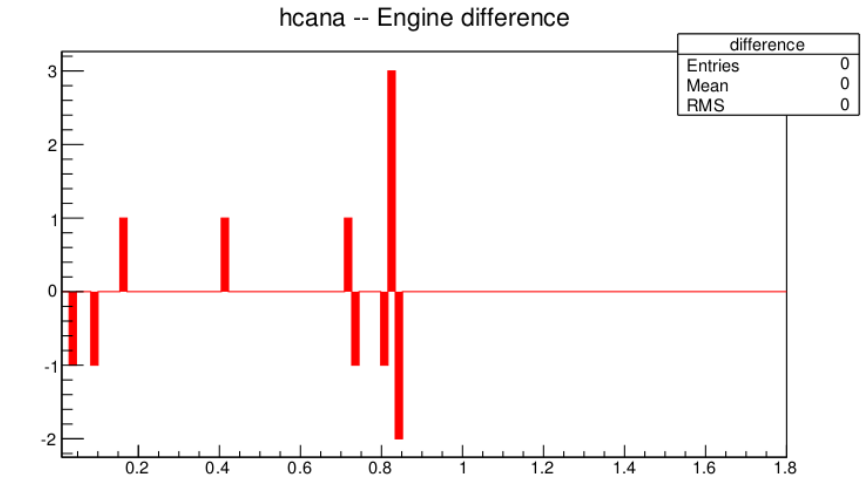
```
// Decide if a hit is neighbouring the current hit.
 // Two hits are neighbours if share a side or a corner.
 //
 bool isNeighbour(THcShowerHit* hit1) {      //Is hit1 neighbouring this hit?
   Int_t dRow = fRow-(*hit1).fRow;
   Int_t dCol = fCol-(*hit1).fCol;
   //    return TMath::Abs(dRow)<2 && TMath::Abs(dCol)<2;
   return (TMath::Abs(dRow)<2 && TMath::Abs(dCol)<2) ||
     (dRow==0 && TMath::Abs(dCol)<3);
 }
```

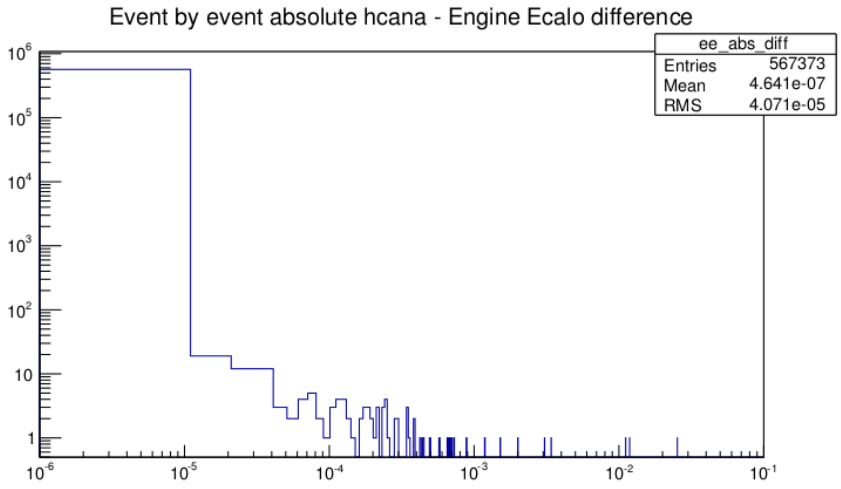
Combine isolated small energy hits (from noisy channels) with big clusters.

hcana – Engine (golden track – best track) comparison









Run 52948, full replay, total number of analyzed events ~600K. *Same* golden/best tracks are compared. *The beta cut is not used*. **Difference in energies is mostly due to rounding errors**.

Summary

- **Calibration for HMS calorimeter in hcana is done:**

Two step process – replay the run and calibrate the replayed run

The Obtained calibration constants match the Engine results

- **hcana – Engine (golden track – best track) comparison** *shows minor differencies - mostly caused by rounding errors*